State-of-the-Art Lectures, Invited Symposia, Keynote Addresses, Poster session: Sex differences in the relationship between intelligence and cortical activation

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Abstract

Several studies have reported negative associations between the whole cortex's activity or even the whole brain's activity under cognitive load and psychometric intelligence for men. In the present study the relationship between intelligence and spatiotemporal patterns of cortical activation during the performance of elementary cognitive tasks was examined for both sexes. In the EEG, the event-related desynchronization (ERD) was quantified, which can be interpreted as a correlate of cortical activation. The results reveal that lower IQ men show a comparatively more unspecific and stronger activation than higher IQ men. Remarkably, no such differences were found for women.

Introduction

An important line in reasearch on human intelligence focusses on study physiological correlates of intelligence. In a variety of recent studies different methods were used to analyze the involvement of the whole cortex in cognitive ability.

Positronemissiontomography (PET): When participants' metabolism was measured during cognitive activity mainly negative relationships between glucose metabolism rate (GMR) and psychometric intelligence have been found, i.e., more intelligent participants displayed less GMR (e.g. Haier et al., 1988). This finding is usually interpreted in terms of neural efficiency: Brighter individuals are characterized by a more efficient use of the brain; their brains consume less energy, presumably because they "use only a limited group of brain circuits and/or fewer neurons " (e.g., Haier et al., 1992). Although the PET-method has the advantage of a high spatial resolution it has the shortcoming of a weak temporal resolution.

Event Related Desynchronization (ERD) mapping: *ERD* mapping (see Pfurtscheller et al., 1988) is an advanced EEG technology which allows to study short lasting changes of cortical activation and – at the same time – providing a relatively high spatial resolution. The main outcomes of existing *ERD*-studies reveal a comparatively unspecific and stronger cortical activation in lower IQ partipants during performance of elementary cognitive tasks, whereas higher IQ participants are characterized by a stronger focus of their cortical resources on those cortical areas that are required for task performance, resulting in less overall activation as compared to the lower IQ individuals (e.g., Neubauer et al., 1995; 1999). These findings are in line with the hypothesis of a more efficient use of the brain in higher IQ individuals. A restriction of existing studies is that they have only been conducted with male subjects.

Research aims of the present study are (1) a replication of existing findings of a more efficient use of the brain in higher IQ individuals, (2) an examination of the relationship between intelligence and cortical activation for both sexes, (3) an analysis of the effects of task complexity on cortical acitivation.

Methods

Participants: From a sample of n = 152 people 51 participants (n = 26 males, n = 24 females) were selected by means of their intelligence scores (BIS, see below).

Psychometric Intelligence Test: The Berlin model of Intelligence Structure test (BIS; Jäger, Süß & Beauducel, 1997) is a bimodal hierachical model for describing broad intellectual abilities in the framework of four operational components and three content based components.

Stimulus Materials: In the letter matching task (Posner & Mitchell, 1967) it has to be decided whether two letters presented on a trial are either phsically the same (i.e., Physical Identity or PI-test) or semantically the same (i.e., Name Identity or NI-test). While the PI-test only demands a visual discrimination the NI-test additionally requires an access to highly overlearned material from the long term memory.

EEG Recording and Quantification of ERD: EEG was measured by means of 29 gold electrodes; signals were amplified by a Nihon Kohden amplifier with a sampling rate of 128 *Hz*. Each EEG trial

started 4000 *ms* before a warning stimulus. The intervall from 1500 to 500 *ms* before the warning stimulus served as reference for the *ERD* calculation. The event related period used for EEG analyses presented here was from 250 to 125 *ms* before the response. The percentage decrease (or increase) in alpha-power from the reference interval (*R*) to the event related interval (*A*) was calculated using the equation: $\%ERD = [(R - A)/R] \times 100$.

Intelligence and cortical activation: Analyses of the patterns of cortical activation for the two IQ groups display a general focus of activation on posterior sites, while frontal areas show no or only weak desynchronization. There are only weak differences between the two IQ groups, which do not reach significance. This unexpected finding can be explained by a suprising gender-effect on the relationship between intelligence and cortical activation (see below).

Sex differences in the relationship between intelligence and cortical activation: The results for men are in line with the neural efficiency hypothesis and illustrate that lower IQ men are characterized by a comparatively unspecific and stronger global activation, wheras higher IQ men show a strong focus of their cortical resources on posterior areas. The probably most remarkable finding for the high IQ men is the deactivation of frontal areas. This frontal region, which is presumably scarcely involved in task performance, therefore provide the best distinction between low and high IQ men. In females the IQ group differences in cortical activation are much weaker and do not reach significance.

Task complexity and cortical activation: With respect to the neural efficiency hypothes is the results for the two different complexity conditions in the letter matching test are comparable. Complexity-related differences can be observed with respect to the global activation level with a stronger activation in the more complex NI-test than in the less complex PI-test.

Conclusions

For male participants it can be concluded that the 'neural efficiency hypothesis' has received further support in our study.

The higher neural efficiency of brighter individuals seems to be characterized not only by their presumed use of fewer neurons or neuronal circuits within those areas required for task performance but also by the ability to deactivate or inhibit other areas.

Biological explanations for these findings refer to (1) individual differences in the brain organizational development (Haier, 1993). A failure in the process of a synaptic density decrease (i.e.,'neuralpruning') in the early teen years might result in too many redundant synaptic connenctions and this might beacause of mental retardation. (2) individual differences in brain myelination (Miller, 1995). A stronger myelination of axons in the cortex should have the effect of a higher speed of neural transmission, less leakage and cross-talk between neurons.

Refering to the unexpected findings for the female participants, which have been observed in the present study for the first time, we do not have a sufficient explanation. Although some studies provide evidence and also preliminary explanations for sex-related differences in cortical activity, these studies do not focus on sex differences in the relationship between intelligence and cortical activity during cognitive load. In our view various replications of the findings presented here are necessesary, before any firm conclusion should be drawn.

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